BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Flight Planning Study - Review of Gemini Flight Plans - Case 610

DATE: March 1, 1968

FROM: B. H. Crane

ABSTRACT

An analysis of basic types of variables and constraints involved in writing Gemini flight plans is summarized in this memorandum. In writing a flight plan, it is useful for the flight planner to have a means of integrating constraint data from a variety of sources as it evolves. His decisions regarding the schedule of flight-crew and related ground-station operations influence these constraints. The Gemini analysis illustrates types of variables by which a flight plan and associated constraints can be built up as an internally consistent body of data for subsequent scheduling or updating.

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MEMORANDUM FOR FILE

I. INTRODUCTION

The review of Gemini flight planning summarized in this memorandum reports one aspect of a study initiated at the request of MSC late in 1966. The study was requested by J. P. Loftus, Chief, Operations Integration Branch, ASPO, and J. B. Jones, Chief, Flight Planning Branch, FCOD. Broadly stated, the overall task was to make an analytical study of the flight-planning process, define its basic functions, and describe it in terms of specific variables. As defined in this study, flight planning refers to those aspects of planning a mission that are primarily directed toward issuing flight plans. The flight plan outlines a nominal sequence of spacecraft and related ground-station operations by which to achieve a designated set of mission objectives. Although writing a flight plan is an integral part of mission planning, it is useful to distinguish flight planning from other closely related areas, such as mission-support, trajectory, or recovery planning.

Analysis of flight planning was based upon a study of flight plans for Gemini missions. The later Gemini missions in particular illustrated many factors associated with rendezvous, a variety of experiments, EVA activities, and other earth-orbital operations that are expected to be encountered in future programs. A completed set of nominal flight plans on which to base the analysis was available from the Gemini program. These flight plans were compiled by a small group of experts who coordinated them with other mission-planning functions. Discussion with the flight planners of the factors that had to be considered in writing these documents was an essential aspect of this review.

This study was intended to contribute to the handling and coordination of flight-planning information for increasingly complex missions. Mission complexity adds to both data requirements and diversity of sources, and longer mission durations will lead to greater need for real-time flight planning. It was indicated that further structuring of flight-planning data to facilitate flight-plan evaluation and compliance with constraints would be a useful result. An analytical study was also needed as a part of the evaluation of computerized information handling in pre-mission or real-time flight planning. As the study progressed, an attempt was made to structure the information and variables so as to be adaptable to storage and retrieval by an automated system.

Definition of the problem in more specific terms resulted from substantial initial study of the information in the flight plans, implied systems functions, and mission-planning interfaces. In examining a variety of factors, it was found that some of the variables that influence the flight plan are either constrained or largely determined in other areas of mission planning. An important function of the flight planner is to synthesize constraint information from many sources. Pertinent constraints can arise from system or environmental characteristics; they may represent mission planning decisions, or they may result from previous decisions made by the flight planner. A focus on this aspect of flight planning was adopted for analysis as a basic consideration in the organization of flight-planning data and the definition of variables.

The results summarized in the following discussion present a particular approach to constraint analysis for flight planning. These results illustrate how basic types of variables and relationships affect an allowable sequence of operations as observed in Gemini flight plans. The variables defined would also have application to other aspects of flight planning, such as acheiving an efficient use of crew time or other consumables over a mission. The focus on constraints, in addition, is relatively free of assumptions about program-specific objectives or special criteria for flight-plan optimization.

An additional phase of the study was the examination of a basic model to further analyze the variables and the logic of constraint analysis. This exploratory model, to be described in a separate memorandum, was developed in parallel with the Gemini study and is similar in concept. The model, however, is illustrated in terms of typical Apollo or AAP variables. It is primarily concerned with studying a particular formatting and organization of the variables and identifying logical functions required to operate on them. The Gemini study, on the other hand, relates types of constraints that could be represented within this framework to required temporal relationships among mission operations in a flight plan.

II. OBSERVATIONS ON FLIGHT-PLANNING DATA

The primary function of the flight plan during a mission is to provide an overall schedule of operations for the flight crew and ground-support personnel. Special operations such as launch, reentry, rendezvous, EVA, or experiments are executed by the crew from separately-carried procedures books. A summary format of the flight plan is prepared for mission use and is issued as one section of the flight-plan document. The summary flight plan identifies major operations and key transitions of spacecraft systems, such as guidance modes, on a scale of ground-elapsed time (GET).

It also incorporates pertinent mission events such as revolution numbers, station passes, and day/night cycles of the orbiting vehicle. This format is easily updated by shifting blocks of procedure or events on the time scale. Since the nominal flight plan provides a common base of information for the crew and the ground, it greatly reduces the need for air-ground communications in coordinating or updating of the mission schedule.

One essential aspect of data organization for the flight plan is the identification of appropriate blocks of crew procedure to correspond to flight-plan use. Segments of mission procedure that are scheduled or updated as units are referred to as activities in this study. A discussion, categorization, and illustrative list of Gemini activities is contained in Appendix A, as derived from flight plans for GT-8 through GT-12. The activities identified vary from entire phases, such as launch, to simply a transition of a single switch. Appropriate choices evolve along with the mission objectives, the design of the system, the writing of crew procedures, and scheduling in the flight plan. They may vary considerably for different types of missions or may be dependent upon specific characteristics of the mission plan. Major characteristics of the activity definitions illustrated in Appendix A include the following:

1. Reference to a basic system-operating procedure,

2. Provision for scheduling or re-scheduling an activity separately as a unit,

3. Convenience in specifying requirements associated with the activity,

4. Completion of a defined mission pay-off, and

5. Indication of an important state transition for entry in the summary flight plan.

A second facet of the flight-planning problem is definition of the relevant data at an appropriate level of detail. The information contained in the summary flight plan is considerably less than that necessary to assess detailed conditions that may be required to schedule an activity. Some of the supporting information for Gemini flight plans was supplied by the <u>Gemini Operations Handbook</u> and a reference trajectory. Additional procedures and a detailed flight plan were also issued as a part of the flight-plan document. Detailed flight plans provided, as one function, a means of tracking major system and crew states throughout a nominal sequence. Profiles of attitude-control mode, platform mode, and computer mode were displayed individually in vertical columns beside procedural entries, since they represented major states in the hardware configuration. These plans were generally included for launch, reentry and rendezvous where applicable. Full detailed flight plans were written for the early Gemini missions, omitted for the longer-duration missions such as GT-5 and GT-7, and were written for the Rendezvous/EVA missions GT-8 through 10. As the flight planners and other personnel gained a highly detailed knowledge of specific mission types, the need for a detailed flight plan decreased. This level of detail, however, is indicative of the information required for constraint analysis.

Several observations on the coordination of flight planning with other mission planning functions are also pertinent to organizing the data in a useful manner. Timeline data on crew operations evolves with and influences mission planning from its early stages to final simulations and planning of crew training. As the definition of crew activities and procedures develops along with planning trajectories and other mission profiles, the level of detail at which they are interfaced increases. The data structure should be capable of accommodating information at varying levels of detail for preliminary planning as well as for final planning. In addition, the iterative nature of mission planning makes it desirable to organize the data so that final constraints do not depend upon the particular order in which information was received. It should also be possible to schedule activities in any order without precluding an available flight-plan solution. The strategy by which the flight planner elects to schedule them, however, unavoidably constrains his subsequent choices. The following discussion illustrates an approach to constraint analysis that meets these general characteristics.

III. APPROACH TO CONSTRAINT ANALYSIS

In order to specify flight planning data in terms of variables, it is advantageous to view the flight plan as a series of profiles in mission time. Ground-elapsed time (GET) from lift-off to splashdown provides the basic time reference for sequences of activities and related profiles. The activity profile is described in terms of activity names and times at which they are scheduled, such as time of initiation or termination of an activity. Other profiles of interest in flight planning include states such as day/night cycles, spacecraft attitude, control modes, or electrical power that are related to some activities.

A system state variable, in this context, is defined by a set of values that can be assumed throughout a profile. These values may be numeric, as attitude coordinates or usable propellant, or they may be alphameric, as crew locations or discrete states of a hardware system. Variables identified to express requirements and constraints on Gemini activities are discussed and illustrated in Appendix B. In addition to activities and time, six categories of state variables are included:

1. Trajectory
2. Attitude
3. Configuration
4. Hardware Systems
5. Crew
6. Consumables

A constraint on one of the variables is a limitation of the values that the variable can take on. Constraints on the types of variables identified could be defined by using arithmetic or logical relations such as $\leq$, $\geq$, =, $\neq$, "AND", "OR", "NOT". The constraints of interest in flight planning must account for both state and time. Constraints on an activity generally refer to a limitation on the times at which the activity can be scheduled.

The structure of constraints in the flight plan is analyzed as relationships among activities and states of other profiles. A constraint on one of the variables within this structure may have its source in states of another variable or activity, which is said to require the object constraint. Four types of requirements are of potential interest:

1. Activity to activity
2. Activity to system state
3. System state to activity
4. System state to system state

This study examines requirements associated with activities. System-state to system-state relationships among the variables are categorized as internal logic; they are briefly discussed in Appendix B. System-state requirements associated with an activity may apply at initiation of the activity (spacecraft initially docked for Agena ion-wake measurement--Experiment S-26), over the duration of the activity (16 mm camera on during Agena thrust), at specific locations in orbit (spacecraft attitude "heads up" in the South Atlantic Anomaly region), or some other interval relative to scheduling the activity (Experiment S-4 TEMP-COLD at all times prior to conducting the experiment).

Two characteristics of the analysis are particularly influential in the results. First, the requirements analyzed are timeline conditions implied by scheduling a single activity. This feature provides an overview of the types of constraint data that could be stored and processed by activity in an automated system. Second, requirements are defined only with respect to internal consistency of the profile description, even though only partially completed. Requirements for completing the plan would have to be listed as well, if not implied by a scheduled activity.

IV. ILLUSTRATION OF GEMINI FLIGHT PLAN CONSTRAINTS

In Gemini flight planning, constraints were often expressed temporally to account for required system maintenance or information flow. A number of activity requirements in Gemini could be specified directly in terms of time. In the spacecraft systems area, for example, the flow of coolant in the environmental control system had to bypass the radiators on the adapter section during launch because of aerodynamic heating. Residual cooling during launch was obtained from a pre-launch heat exchanger and maximum flow through an evaporator. Thermal control in orbit required a transition to normal flow for both radiators and evaporator. Requiring RAD-FLOW and EVAP-NORM at nominally 35 minutes and 40 minutes into the mission, respectively, provided for sufficient cooling of the space radiators.

In the area of crew requirements, astronaut sleep periods were scheduled nominally according to their pre-mission sleep cycle. A constraint of this kind could be converted into GET once a lift-off time had been established. A more concise specification of this constraint could be realized in an expanded framework by requiring the activity "sleep" whenever the profile of Greenwich Mean Time (GMT) was within appropriate hours. The GET constraints on successive sleep periods and a requirement that they be scheduled, however, are equivalent for flight planning.

Temporal structure among activities can also be specified directly with respect to single activities by requirements of the form that a supporting activity be scheduled within a given interval of time relative to the primary one. A constraint on accuracy of the inertial platform during thrust, for example, was handled by a requirement that a platform alignment be completed nominally within ten minutes of a maneuver. The relative-time constraint is considerably more practical for the flight planner in this case than predicting and tracking platform drift as a system state.

A required frequency can also be realized by a series of individual activity requirements for a repetition within a designated interval. In preliminary flight planning, fuel-cell purges were scheduled by nominal relative-time constraints--one purge approximately every six hours. Since the formation of dendrites in the cells correlates with power drawn, the constraint would become a maximum number of ampere-hours between purges in final planning. Frequency constraints might also cover information requirements for mission support, such as a Gemini tape playback by a ground station once per revolution.

Alternatively, temporal constraints on activities are implied by their relationships to other profiles. Trajectory-related profiles, such as day/night, station coverage, and visibility of stars or landmarks provide obvious examples. Variations in these profiles are determined by solutions of the trajectory, which includes a required sequence of translations at specific mission times. Most activities do not have any appreciable influence on the trajectory,however. For them, the impact of requirements for trajectory-related variables is to limit the activity to certain intervals of mission time. Planned landing area (PLA) updates and Go/No-Go procedures were actually scheduled by requiring a specific station pass and revolution number, requested by the retrofire officer.

Experiment D-14, UHF-VHF Polarization, was highly constrained in time by a requirement for specific stations. Hawaii and Antigua were the only stations equipped with special receivers needed for the experiment. The number and distribution of high-elevation passes available while the astronauts are awake is affected by additional variables, such as station latitudes and the lift-off time of day. These intermediate variables are accounted for in trajectory planning. Other trajectory-related factors that influenced the scheduling of Gemini experiments included flight path relative to the Earth's magnetic field lines, conditions of the ionosphere, and the radiation environment of the spacecraft.

Sequential requirements among activities may be implied by an activity requirement for a particular system-state, if the states of the required profile are controlled only by another activity. A bending-mode test had to be done in a docked configuration, for example. A requirement for the spacecraft to be in a docked state has the effect of requiring a previous activity "docking" with no intervening undocking. Similar constraints apply to the data-gathering modes of Experiment D-10, Ion Sensing Attitude Control, which required special ion sensors in an extended position. Sensor deployment and equipment activation was accomplished by Mode A of the experiment, which had to be done first. Another mode collected data during thruster firings, which ended in severe degradation or destruction of the sensors, and this mode had to be done last. A variable giving the three states of the sensors and requirements that data-collection modes be initiated with the sensors in the deployed but active state would insure the required sequence.

Because the transitions of the sensors for Experiment D-10 are irreversible, the requirement for Mode A to be done first could also be written temporally without tracking a state variable for the sensors. A state variable would be needed, on the other hand, to write activity requirements that would acheive the proper sequence for the last mode of the experiment within the framework of this analysis. Again the transition is an irreversible one, but the final mode of the experiment is not a requirement for other modes. Another constraint of this type resulted from jettisoning the docking bar to release the tether at the conclusion of tethered station-keeping. All activities requiring docking or a docked configuration had to be done prior to tether deployment, since docking could not be done with the tether in the way. An additional requirement for the tether to be stowed would have to be associated with each of these activities to obtain the desired logic.

When an activity does control system states, relationships to other activities derive from the condition that required states must be available at the indicated times. Spacecraft attitude requirements illustrate some alternative cases. Experiment S-9, Nuclear Emulsion, required a BEF (blunt-end-forward) orientation while in the South Atlantic Anomaly region, and pitch and roll were constrained to be zero ± 15 degrees. If desired, an alignment mode of the platform (BEF) could have been scheduled simultaneously because the $(0°,0°,0°)$ orientation required for it would be one of the allowable orientations for S-9. A requirement to track a celestial or earth reference, on the other hand, requires attitude coordinates to vary over the duration of the activity in a prescribed manner. Every value of attitude required along this profile would have to be acceptable to schedule another activity simultaneously.

In a different category of variable, requirements for states of a subsystem or for use of a power outlet for auxiliary equipment cannot conflict at any one time. Sufficient time must also be allowed for transitions of the states where applicable. Within a single block of procedure, potential conflicts of this type should be worked out, but they apply to flight planning where these procedures may overlap in the timeline. For larger spacecraft with more crew members, coordinating multiple procedures at one time is expected to become more prominent in flight planning than it was in Gemini.

V. CONCLUDING REMARKS

To summarize profile constraints, necessary conditions that must be realized are as follows:

1. For each mission time, all system states required at that time by scheduled activities are present or available.

2. For each mission time, combinations of states required and created by all activities are internally consistent.

3. Temporal variations in the system-state profiles are consistent with constraints on the profiles, including any necessary transitional activities.

4. Required sequence, relative time, and times of activities are within allowable limits.

5. Summable quantities allowable over the mission or portions of the mission have not been exceeded.

6. All activities that require scheduling in the flight plan to support mission objectives, real-time mission support, and contingency requirements have been scheduled.

Accounting for all activities required to complete a flight plan is not directly incorporated in the logic of the scheme described in this memorandum. Only requirements for supporting activities or frequency requirements can be manipulated along with a single activity. To complete this logic, it is essential to keep track of other required activities that are not scheduled. Information concerning the total number of trials of an experiment or total exposure time for a micrometeorite collector, for example, falls in this category.

Within a framework of requirements associated with individual activities, it was found that the major types of temporal structure among them can be accounted for by state variables. Advantages of structuring constraint data in this manner include the ability to manipulate constraints along with individual activities. Timeline constraints associated with the trajectory or other sources can also be defined in comparable terms. The profile representation of flight-plan constraints offers flexibility in both the building up of constraints and in the manner in which activities are scheduled.

In addition to providing constraint information, many of the variables involved in tracking Gemini constraints were also of interest in flight-plan optimization. Decisions as to when the spacecraft should be docked to the Agena is one example. The profile was influenced by many activity requirements, but a major parameter in constructing it was spacecraft propellant. While docked, spacecraft attitude stabilization or the capability to alter cardinal headings could be controlled by the Agena. When control from the spacecraft was needed, however, it required additional propellant in a docked configuration. In formulating a strategy, the flight planner would have to weigh these considerations against the cost of docking, undocking, and station keeping, as well as against other activity requirements.

As indicated by Gemini flight plans, precise correlation between procedures and time is not needed to schedule many activities. Alternative means of scheduling include the following: assignment of a particular GET, designation of an interval of GMT or sidereal time on a specified day, placement relative to an event time such as T_R for retrofire, specification of a particular night pass or station pass, or simply definition of position in a sequence. It would be advantageous to select the appropriate means of tying activities to the data structure for the purpose of monitoring changes in the flight plan in real time.

Finally, the fact that the system-state variables are not independent introduces undue complexity into the logic if too many dependent variables become involved in representing the temporal structure. Applicable requirements for all variables must be written for each activity, even though a constraint on one of them, such as GET, is sufficient to schedule the activity. The utility of extending the scheme to constrain temporal relations among some activities directly should also be evaluated as a means of reducing the number of state variables.

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APPENDIX A

Organization of Activity Data for Flight Planning

Segments of mission procedure, called activities, provided the basis for analyzing requirements and constraints in this study. Selection of appropriate unit activities for scheduling in the flight plan is discussed in this appendix. In an automated system, flight planning data would be at least partially structured by the manner in which activities are defined. The categorization and selection of activities illustrated for Gemini, however, is not intended to suggest a final structuring of activity lists for accessing in such a system.

Table A-1 indicates many of the activities that were identified from summary flight plans for GT-8 through GT-12, supplemented by a study of detailed flight plans and procedures. The table is categorized by types of operations such as nominal, rendezvous, EVA, or experiments. Numbered entries (1, 2, ...) in each category identify specific activities, and lettered entries under them (a, b, ...) represent different modes or sub-units of the activity. Selection of these modes or sub-units is based upon the manner in which they were flight-planned in the particular missions analyzed.

Useful characteristics of activities defined for flight planning are identified as follows:

1. Reference to a basic system operating procedure
2. Provision for scheduling or rescheduling an activity separately as a unit
3. Convenience in specifying requirements associated with the activity
4. Completion of a defined mission pay-off, and
5. Indication of an important state transition for entry in the summary flight plan.

These characteristics overlap in many cases. A docking or undocking, for example, could be identified as an activity by all five. It is a basic system operating procedure, is scheduled separately as a unit, has a unique set of activity requirements, and in the case of a docking practice, completes a mission objective. In cases where a docking or undocking was included as a part of a larger procedure, it was still flight planned separately, as in the undocking at initiation of Experiment S-26, Ion Wake Measurement. The following examples briefly illustrate some additional factors that were noted in attempting to list the unit activities for flight planning.

For economy of data specification, it is desirable to identify a basic procedure as a separate activity if is is included several times in other activity definitions. An OAMS thrust, for example, has a standard group of requirements associated with it and should have to be listed only once for specification of these requirements. The standard requirements for an alignment of the inertial platform or an update from the ground prior to the maneuver could also be associated with the standard procedure. The supporting update or platform alignment is identified as a separate activity to be scheduled, however. Specific maneuvers, which have separate requirements for propellant and mission time, are listed under rendezvous or operational objectives. Reference to requirements for the standard procedure would always be included under each specific maneuver. Special requirements that on-board navigation activities be done before some of the GT-10 rendezvous maneuvers would also be associated with the particular maneuvers.

In addition to the supporting activities for maneuvers, a number of other system-state transitions must be defined as separate activities to be scheduled where needed in completing the flight plan. Examples are establishing a new attitude, powering up the spacecraft, or switching the rate gyros to "on." The list of such transitions for both spacecraft and Agena is incomplete but representative. Sometimes procedural items such as throwing one or two switches fall into the category of separate transitional activities because of the manner in which they are scheduled. Normally switching the mode of C-band beacons on the reentry and adapter sections of the spacecraft (ground command or continuous) was accomplished by standard checklists such as the post-rendezvous checklist or a reentry checklist. A separate activity had to be identified and scheduled, however, to switch C-Rnty - CMD and C-Adapt - CONT to transition from launch to rendezvous configurations.

For utility of the flight plan, it is necessary to list some operations that are not scheduled separately but are part of a larger activity. In an automated system they could be identified as comments to be printed out whenever the primary procedure is scheduled. Starting and stopping of the Agena recorder or the 16 mm camera surrounding a docking maneuver or a docked Agena translation could be incorporated in this manner. Several additional examples occur in the closed-loop rendezvous sequence in the rendezvous procedure. Closed-loop rendezvous was initiated by depressing the computer start key. This event is entered in the summary flight plan primarily because it represents a key transition of state. Timing of this event is determined in real time by an established procedure for crew monitoring of data points generated in the rendezvous computer mode. Timing for the nominal case derives from the reference trajectory. The transition is flight planned in the sense that it is called out as a part of the nominal procedure.

In a number of cases, an activity that is required by a mission objective is scheduled in the flight plan only as a part of another procedure. Experiment D-12, Astronaut Maneuvering Unit, was included in the GT-9A flight plan entirely within the EVA procedure. The MSC-3 experiment on GT-10 was completed simply by scheduling the insertion and pre-retro checklists. In each case the experiment did not appear as a separate activity in the summary flight plan.

Some operations in Gemini were not included in the flight plan but were scheduled in real time during the mission. A VOX adjust, for example, was normally not flight planned in the latter missions, and the reporting of completed checklists to the ground was also not specifically scheduled. Station passes over which standard voice procedures were observed were only scheduled implicitly on the basis that they not interfere with other activities. Specific modes of other activities were not specified in the flight plan, even though the activity was scheduled. Real-time planning included specific land-areas or weather phenomena to be photographed under experiments. Data collection modes for some experiments did not affect the scheduling of the experiment and were not specifically flight planned. The various modes of operating the photometer for Experiment D-5, Star Occultation Navigation, are examples. Activities or modes of activities that were not specifically flight planned are not included in the typical activity definitions in Table A-1.

Specific choices of activities for flight planning are expected to vary among different types of missions and even among particular missions of the same general type. Appropriate definitions are influenced by the mission objectives, characteristics of the mission plan, how procedures are written, and transitional requirements of the systems. Even the flight plan can introduce requirements for additional partitioning, as in the case of defining a preliminary EVA preparation in GT-10, occasioned by an intervening dual-rendezvous maneuver.

TABLE A-I

Gemini Activities Illustrated from GT-8 to GT-12

I. LAUNCH AND REENTRY

A. Lift-off to Insertion

1. Launch Sequence through IVAR
2. Insertion Checklist

B. Retrofire Preparation to Post Landing

1. Load Reentry Module Tape
2. Reentry Self Mode Check
3. Reentry Updates
4. Preretro Checklist
5. Back-up Reentry Updates
6. Reentry Sequence from T_R-22 min. to S/C Egress

II. BASIC ORBITAL PROCEDURES

A. Mission Support and Communications

1. Nominal Station Pass
2. C-ADAPT - CONT, C-RNTY - CMD
3. Gemini Tape Playback
4. Agena Tape Playback
5. Flight Plan Report
6. Flight Plan Update
7. Go/No Go for (Rev-PLA)
8. 1-4 Reentry Update
9. PLA Update
10. Update for OAMS Translation
11. Update for Agena Translation (Docked)
12. V_M Load for Agena Translation
13. V_M Check for Agena Translation
14. Crew Status Report
15. Digital Clock Update
16. Accelerometer Bias Update
17. Go on RAD.

B. Crew Personal Activities

1. Eat Period
2. Sleep Period

C. System Checks and Maintenance

1. Fuel Cell Purge
2. Cryogenic Quantity Readout
3. RAD - FLOW, EVAP - NORM
4. Accelerometer Bias Check
5. Communications Check
6. Scanner Check
7. VOX Adjust

TABLE A-I (Continued)

D. Spacecraft Operation and System Transitions

1. Power up Spacecraft
2. Power Down Spacecraft
3. Platform Alignment
4. OAMS Thrust
5. Control S/C Attitude to (_°, _°, _°)
6. Load Module (__)
7. Set Event Timer
8. Attitude Control - (__)
9. Platform - (__)
10. Computer - (__)
11. Rate Gyros - (__)
12. RCS Heaters - (__)

E. Agena Operation and System Transitions

1. Flight Control Mode - (__)
2. SPC Load/Disable
3. Gyrocompass to (Cardinal Heading)
4. PPS/SPS Thrust
5. L-Band System - (__)
6. Approach Lights - (__)

III. RENDEZVOUS

A. Maneuvers

1. Height Adjust
2. Phase Adjust
3. Plane Adjust
4. Corrective Combination
5. Circularization
6. Circularization Adjust
7. TPI
8. First Midcourse
9. Second Midcourse
10. Velocity Match
11. Rendezvous Separation
12. Midcourse Correction for Rendezvous

B. Rendezvous Updates

1. Maneuvers
2. Trajectory data
3. Target-Vehicle Acquisition Data
4. Terminal Phase Back-up.

C. On-Board Navigation

1. Horizon Calibration
2. First Orbit Determination
3. Ascent Vector Translation Determination
4. Orbit Determination, Final Phase
5. Orbit Determination Translation Determination

TABLE A-I (Continued)

D. System Tests and Transitions

1. Radar Lock-on
2. Test Rndz.
3. Comp. - Rndz.
4. Start Comp. - Push
5. Extend Docking Bar

IV. OPERATIONAL CHECKS AND OBJECTIVES

A. S/C - Agena Operations

1. Dock
2. Undock
3. Formation Flying or Station Keeping
4. Pre-Sleep Checklist
5. Electric-Charge Monitor Test
6. Bending Mode Test
7. Platform Parallelism Check
8. SPC-Loaded Yaw Maneuver
9. Tethered Station Keeping
    a. Spun-up
    b. Gravity-Gradient Stabilization
10. Final Separation Burn

B. Extra Vehicular Activity (EVA)

1. EVA Preparation
    a. Preliminary EVA Preparation
    b. Final EVA Preparation
2. Update EVA Sunrise Time
3. Go/No Go for Depressurization
4. Depressurize Cabin and Open Hatch
5. EVA
    a. Stand-up
    b. Umbilical
6. Ingress
7. Close Hatch and Repressurize Spacecraft
8. Post Ingress Procedure
9. Equipment Jettison
10. Post EVA Procedure

C. Additional Objectives

1. Apollo Landmark Investigation
2. Apollo Sump-Tank Camera Test
3. ATM Exercise

TABLE A-I (Continued)

V. EXPERIMENTS

A. Department of Defense

1. D-3: Mass determination

   a. Calibration burn
   b. Mass determination burn

2. D-5: Star occultation navigation

3. D-10: Ion sensing attitude control[2]

   a. Mode A: Equipment extension and activation
   b. Mode B: Ambient data accumulation
   c. Mode C: Roll attitude study
   d. Mode D: Pitch attitude study
   e. Mode E: Yaw attitude study
   f. Mode F: Photo emission effects
   g. Mode G: Random data accumulation
   h. Mode H: Translation thruster effects

4. D-12: Astronaut maneuvering unit

5. D-14: UHF-VHF polarization

   a. Mode 1: With platform and computer
   b. Mode 2: Without computer
   c. Mode 3: Without computer and platform

6. D-15: Night image intensification

   a. Mode 04: Thruster effects

7. D-16: Minimum reaction power tool evaluation

B. Manned Spacecraft Center

1. MSC-3: Tri-axis magnetometer (M-405)
2. MSC-5: Lunar UV spectral reference
3. MSC-6: Beta spectrometer (M-408)

   a. Mode A: Controlled attitude
   b. Mode B: Controlled roll rate

4. MSC-7: Bremsstrahlung spectrometer (M-409)

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[2]Modes are as defined for GT-10. Modes B and F were combined as Mode E in GT-12 and other modes re-lettered accordingly.

TABLE A-I (Continued)

5. MSC-8: Color patch photography
6. MSC-12: Landmark contrast

   a. Mode A: Boundary observations[3]
   b. Mode B: Daylight lunar calibration
   c. Mode C: Night lunar calibration
   d. Mode D: Planetary calibration
   e. Mode E: Cloud deck calibration

C. <u>Science</u>

1. S-1: Zodiacal Light Photography[4]
2. S-3: Frog Egg Growth

   a. Heater-on
   b. Activation (GT-8 only)
   c. Fix right-hand or left-hand unit

3. S-4: Radiation and Zero G Effects on Blood and Neurospora Cells

   a. Mode A: Neurospora package activation
   b. Mode B: Blood package activation
   c. Mode C: Blood and neurospora package deactivation

4. S-5: Synoptic terrain photography
5. S-6: Synoptic weather photography
6. S-7: Cloud top spectrometer
7. S-9: Nuclear emulsion

   a. Experiment package recovery

8. S-10: Micrometeorite crater collection
9. S-11: Airglow horizon photography
10. S-12: Micrometeorite collection

   a. Collector door-open
   b. Collector door-close
   c. Collector door-lock
   d. Experiment retrieval

11. S-13: UV Astronomical camera

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[3]Sequences 01-11 give the coastlines that can be used for Mode A. The ones selected for the nominal flight plan were also called out as part of the activity designation (GT-10 flight plan).

[4]S-1 was EVA on GT-9A and from the cabin on GT-8 and GT-10. Since it had only one mode on each mission, these modes do not need to be distinguished, but the activity requirements would be different for 9A.

TABLE A-I (Continued)

12. S-26: Ion wake measurement

    a. Sequence 1: Day, Earth's magnetic field lines perpendicular to velocity vector.
    b. Sequence 2: Night, Earth's magnetic field lines perpendicular to velocity vector.
    c. Sequence 3: Night, South Atlantic Anomaly region.

13. S-29: Libration regions photography
14. S-30: Dim sky photographs/orthicon
15. S-51: Sodium vapor cloud

    a. First pass
    b. Second pass

D. <u>Technology</u>

   1. T-2: Manual navigation sightings
   2. T-17: Meteoroid erosion

APPENDIX B

Gemini System-State Variables for Flight Planning

This appendix contains preliminary lists of Gemini system-state variables and supporting information that were originally presented to MSC as working papers on March 8, 1967. The Gemini list provided background for preparation of a similar list from the Mission Modular Data Book for an Apollo spacecraft, presented by M. A. Robinson on the same date. In subsequent work on the study, TRW supporting the Flight Planning Branch formatted the Apollo list for use in developing the model referred to previously. Since the Gemini variables were only intended for study, no attempt was made to update this preliminary list as the model progressed.

The selection of system-state variables attempts to specify those states of a Gemini rendezvous mission that a flight planner would, in principle, have to keep in mind. An illustrative list of such variables is included as Table B-1. The categories under which the variables are listed provide a tentative organization. A revised categorization for the model that would also cover the variables listed here is suggested on page 5. The variables defined in the table potentially describe profiles of states across mission time. The right-hand column in the table designates either a dimension for a continuous variable or a field of discrete states that would be needed to construct such a profile.

In selecting applicable variables, it was assumed that flight planning is primarily concerned with the scheduling of orbital operations. The complex, well-defined sequences of state that are previous to the insertion checklist and subsequent to the preretro checklist were excluded from the analysis. Variables are included to describe profiles of orbital states or changes of state specifically noted in the summary flight plans. Additional system-state variables in the list are associated with other requirements of the scheduled nominal operations. To make this representation compatible with procedural data, individual switch positions were specified to define the states of many hardware systems. The following guidelines pertain to the selection of these switch specifications from the full list.

1. Switching provided for redundant functions, such as identical primary and secondary systems, is omitted.

2. The details of power distribution, including circuit breakers, are omitted, except for those functions nominally performed to power down and power up the spacecraft.

3. States of additional equipment provided for experiments are an internal matter to the experimental procedures, except where two experiments used the same equipment, such as a camera, TV monitor, photometer or spectrometer.

A more complete specification would have to be made for applications to malfunctions or contingency planning at a similar level of detail.

The variables identified in this list are not independent. A docked configuration of the Gemini spacecraft and Agena, for example, implies that attitude coordinates are either equal or opposite for the two vehicles, depending on the coordinate and reference system. It also implies that the spacecraft radar not be switched to "On" during this time and that only one vehicle is providing attitude control at any one time. A constraint logic incorporating such variables must assure internal consistency of all states at any mission time and allowable transitions of the states. These profile to profile requirements are referred to in this study as internal logic among the variables.

Using internal logic, some abbreviation of the variables presented would be possible if either (1) some of the switches are nominally in a known position unless required in an other state, or (2) states of different switches are logically identical, so that a given state of one switch always implies a particular state of another switch and vice versa. Any switches in the first category could be omitted, and the second category could be consolidated to a single variable, which might be simply one of the two switches. The logic is usually more complex, however. To illustrate with a relatively simple case, use of the Gemini on-board computer implied obtaining attitude-control power from the Inertial Guidance System inverter (AC Power-IGS). This switch position would still be used if the platform were being used without the computer. With neither the platform nor computer on, the Attitude Control and Maneuvering Electronics (ACME) inverter would normally be used for attitude control to conserve power. A requirement for AC Power - ACME would be fulfilled by AC Power - IGS if either the platform or computer are also in use. The number of states required to specify system configurations also might be consolidated by identifying the state variables as functional configurations, such as Orbital Attitude and Maneuvering System (OAMS) thrust, with implied switch positions. The specification given here is more general, especially for illustrative purposes.

In addition to the state variables, temporal variables of primary interest in flight planning are those associated with activities. Activity profiles may be treated in the logic as analagous to other state profiles by defining the states of an activity to be "scheduled" or "unscheduled." A requirement of the scheduled state may be written against a time reference, which includes ground elapsed time (GET), Greenwich mean time (GMT), or local sidereal time. Alternatively, a requirement that the activity be scheduled would be accompanied by a constraint on a temporal variable associated with it. These temporal variables include:

1. Time of initiation or termination of the activity

2. Duration of the activity

3. Time between activities

4. Frequency of repetitions or total time required.

Variations in state profiles may be a consequence of scheduling an activity that controls them or may be determined by factors other than scheduling activities. Variations that are random cannot be specifically flight planned, such as attitude drift in the absence of a controlled mode. Trajectory-related profiles are nominally predictable, but they depend upon a large number of additional variables not listed in the attachment. Other areas of mission planning such as recovery planning also affect flight planning, but the variables involved are primary to the additional area. The locations of apogee for high-orbit maneuvers, for example, and the number of allowable high orbits in Gemini were constrained by the requirement that one nominal or one contingency landing area be accessible for each orbit. These terms are defined in the Mission Rules according to the state of preparation for recovery that is available in the area. Such factors are considered by the flight planner in making decisions about the overall structure of the flight plan. Since trajectory-related profiles will be highly determined at the point of detailed flight planning, however, only those profiles directly related to activity requirements were included as primary data.

In order to illustrate some of the varied forms of operational requirements from which Table B-I was derived, sample experiment requirements are indicated in Figure B-1. These experiments were scheduled for Gemini 8 through Gemini 12 (except M-5, D-12 and S-51 omitted here). The requirements are presented in terms of variables from Table B-I in the form of a "matrix." Each entry represents a required state for some mode or trial of the experiment on the various missions, as specified by the experimental procedures. Not all entries apply to all modes or missions for which requirements are specified, however. Separate modes are analyzed within an experiment when more convenient to show different requirements for the same variable. A special symbol (*) is entered where multiple alternatives or a profile of states are specified by the experiment procedure. Since this presentation is primarily for illustration, not all variables or relationships among the variables required for a complete specification are represented. Nominal states to which a variable is returned at the end of the experiment are also not included, such as resuming attitude stabilization from the Agena at the end of an experiment when docked.

TABLE B-I

Illustrative Gemini System-State Variables for Flight Planning

I. Trajectory-related variables

A. Spacecraft	
1. Orbit	
a. Rev. No.	1, 2, . . .
b. Previous translation	Symbol
c. Apogee	Nautical miles
d. Perigee	Nautical miles
e. Position of apogee above earth's surface (for a particular rev.)	
1) Latitude	Degrees
2) Longitude	"
f. S/C position above earth's surface	
1) Latitude	Degrees
2) Longitude	"
2. Ground Station Coverage	
a. Identification of station	Symbol
b. Maximum elevation	Degrees
c. Minimum range	Nautical miles
d. Communications and tracking	C(ommand), V(oice), R(adar), T(elemetry)
e. Transmission to MCC	Voice, HSD, WBD, TTY
3. Attitude	
a. Special cases:	SEF, BEF, target vehicle, sun, star, moon, planet, landmark
b. Local attitude coordinates	
1) Pitch	Degrees
2) Roll	"
3) Yaw	"
c. Attitude rates (local coordinates)	
1) Pitch rate	Degrees/sec
2) Roll rate	Degrees/sec
3) Yaw rate	Degrees/sec
4. Illumination	
a. Sun visibility	Day/night
b. Sun elevation	Degrees

TABLE B-I (Continued)

5. Observable phenomena (from the spacecraft)	
a. Star	Name
1) Maximum elevation with respect to spacecraft	Degrees
2) % night pass visible	%
b. Moon	
1) Phase	0, 1/4, 1/2, 3/4, full
2) Position relative to starfield	(Coordinates on star chart)
3) Max. elevation with respect to spacecraft (for a given rev.)	Degrees
4) % night pass visible	%
c. Planet	
1) Position relative to starfield	(Coordinates on star chart)
2) Max. elevation with respect to spacecraft (for a given rev.)	Degrees
3) % night pass visible	%
d. Landmark on earth's surface	
1) Max. elevation	Degrees
2) Min. range	Nautical miles
3) Sun elevation	Degrees
B. Relationship of Spacecraft to Target Vehicle	
1. Special cases	
a. Docking status:	Docked/undocked
b. If undocked:	Formation flying, station-keeping, Agena positioned for rendezvous, Agena parked
2. Relative velocity	
a. Range rate	Ft/sec
b. Azimuth rate of change	Degrees/sec
c. Elevation rate of change	Degrees/sec
3. Position	
a. Range	Nautical miles or feet
b. Azimuth	Degrees
c. Elevation	Degrees
C. Target Vehicle	
1. Ground station coverage (if undocked with spacecraft)	
a. Identification of station	Symbol

b. Maximum elevation	Degrees
c. Minimum range	Nautical miles
d. Communications and tracking	C(ommand), R(adar), T(elemetry)
e. Transmission to MCC	Voice, HSD, WBD, TTY
2. Attitude	
a. TDA cardinal heading:	Forward, aft, North, South, up, down
b. Attitude coordinates	
1) Pitch	Degrees — Target vehicle local coordinate system
2) Roll	Degrees — Target vehicle local coordinate system
3) Yaw	Degrees — Target vehicle local coordinate system
3. Illumination (if undocked with spacecraft)	
a. Sun visibility	Day/night
b. Angle between sun LOS and spacecraft and target vehicle LOS	Degrees
II. Flight Crew	
A. Astronauts	
1. Task involvement	
a. Particular astronaut	C/P/C, P
b. Coordination	CP
2. Location	
a. Pilot	Couch/EVA
b. EVA type	Standup/umbilical
c. Umbilical EVA locations	Spacecraft/Free/Target vehicle
3. Workload	
a. Attention	?
b. Physical work	BTU/hr
B. Personal Equipment	
1. Suit	
a. Helmet	On/off
b. Visor	Closed/open
c. Gloves	On and locked/off
2. Restraint	
a. Couch	Attached/loose/tight
b. EVA	Standup/umbilical/work station
3. Special Equipment	
a. Maneuvering unit	
III. Spacecraft Systems (Selected)	
A. Electrical	
1. Fuel cells	
a. Purge	O_2/off/H_2

TABLE B-I (Continued)

2. Main batteries	
a. Test	On/off/test
3. AC inverters	
a. Power source	IGS/off/ACME
4. Cabin lights	
a. Left and right	Red/off/white
b. Center	Dim/off/bright
5. Exterior Lights	
a. Mode	Dock/off/EVA
B. Environmental	
1. Oxygen loop	
a. Cabin pressure	Depressurized/pressurized
b. Suit fans	No. 1/off/Nos. 1 & 2
2. Coolant loop	
a. Pumps	
1) Primary loop	A. On/off, B: On/off
b. Radiator	Flow/by-pass
c. Evaporator	Max flow/normal
C. Control	
1. ACME	
a. Control mode	Hor. scan/rate cmd./ direct/pulse/re-ent. rate cmd./re-ent./plat.
b. Power on	Pri-sec/off
2. OAMS	
a. Control power	On/off
b. Propellant indication	OAMS-S/OAMS-REG/F/ OAMS-res/. . .
3. Maneuver controller	
a. Preparation for use	Unstowed-on/stowed-off
4. Rate gyros (3)	
a. Power	Pri-sec/off
5. Scanner	
a. Power	Pri-sec/off
6. Reticle	
a. Mounting	Left / right/stowed
D. Navigation	
1. FDI	
a. Scale range	Hi/low
b. Flight Director ref.	RDR/PLAT/Comp
c. Flight Director mode	Rate/Mix/Att.
d. Attitude indicator	With FDI/without FDI/off
2. Platform	
a. Mode:	Off/cage/SEF/orbit rate/BEF/cage/free
b. Alignment	Critical/non-critical

TABLE B-I (Continued)

3. Computer	
a. Mode	Preln/Asc/Nav/Rndz/ Pred. Nav/Re-ent/Orb. det.
b. Module loaded	I through VI
c. MDU power	On/off
d. ATM mode	Stby/auto/rewind/wind/prog.
e. ATM power	On/reset/off
f. Phase of program cycle	Start signal (specific sequence depends upon program)
4. Radar	
a. Power	On/stby./off
b. Angular data and command:	Lock on/no lock on
c. Range (through computer)	10 ft < range < 250nm/not in this range
5. Encoder (Xmit req. radar lock on)	
a. Power	On/off
6. Docking bar	
a. Sequential status	Retracted/extended/ jettisoned
b. Power (additional specialized functions as well)	Dock/off/exp.
7. Event timer	
a. Counting	Up/down/stop
8. Stop time clock	(2 switches here)
a. Counting	Up/down/stop
E. Communications	
1. Voice	
a. Audio Mode	HF-DF/HF/Int./UHF
b. HF	Rnty/off
c. UHF antenna	Rnty/Adapt.
d. Record	Cont/off/Mom
2. C-band beacons	
a. C-Adapt.	Cont./cmd.
b. C-Rnty.	Cont./cmd.
F. Instrumentation (+ Miscellaneous)	
1. TM recorder (DCS)	Cont/off/playback
2. Biomed recorder 1	Cont/off
3. Biomed recorder 2	Cont/off
IV. Target Vehicle Systems (Selected)	
A. Control	
1. Flight-control mode	FC1, FC2, FC3, FC6

TABLE B-I (Continued)

2. V_M	Loaded/verified
3. Stored program commands	Loaded/verified
B. Subsystems (other than control subsystems)	
1. Acquisition beacon	On/off
2. Lights	On/off
3. Telemetry	Record/playback/off
4. L-band system	On/off
5. ACS	On/off
6. PPS	On/off
7. SPS	On/off
V. Spacecraft Consumables	
A. Propellant	
1. OAMS propellants	
a. Weights	lbs.
2. RCS propellants	
a. Weight	lbs.
B. Electrical Power	
1. Fuel cells	
a. Average current	amp.
2. Main batteries	
a. Average current	amp.
C. Life Support	
1. ECS Oxygen	
a. Average rate	lbs./hr. (?)
D. Film and recording tape	
1. Photographic film	
a. Type	Camera designation
b. Particular use	Experiment number
c. Quantity	Feet
2. Voice recording tape	
a. Quantity	Feet (Minutes)

	D-3 CALIBRATION	MASS DET.	D-5	D-10 MODE A	MODE B	MODE C	MODE D	MODE E	MODE F	MODE G	MODE H	D-14 MODE 1	MODE 2	MODE 3	D-15	D-16	MSC-3	MSC-5	MSC-6	MSC-7	MSC-8	MSC-12	S-1	S-3	S-4	S-5	S-6	S-7	S-9 NORMAL	S. ATLANTIC	RECOVERY	S-10	S-11	S-12	S-13	S-26 MODE A OR	MODE C	S-29	S-30	T-2 MODE A	MODE B	T-17
S/C LATITUDE					*														≥15° S			*						*		≥15° S						*	*					
LONGITUDE																			0° 60°			*						*		0°–60°W						*	*					
GROUND STATION												HAW	OR	ANT										*	*													*				
MAX. ELEVATION												>20°	>20°	>20°												*	*															
ATTITUDE (SPEC. CASE)			BEF							*		UP DATE			*	*		MOON			*	*	*			*	*	*		BEF			*		*	*	*		*	*	*	*
PITCH	0°	0°			0°	0°	*	*	0°		0°			HORI	*				0				*			*			±15°	±15°					*		*					
ROLL	0°	0°			0°	*	0°	0°	0°		0°	160°	160°	160°					*				*			*	*		±15°	±15°							*					
YAW	*	−90°			0°	0°	*	*	0°		0°			*	*				0				*												*		*					
PITCH RATE							.1											0					0					0					0		0			0				
ROLL RATE						3												0	*				0					0					0		0		*	0				
YAW RATE								.1										0					0					0					0		0			0				
DAY/NIGHT			N						*						N	D		N			D	D	*			D	D	D			D		N	D	N	*		N	N	N	N	D
SUN ELEVATION																						>30°				>45°		>10°														
STAR			*																				*												*			*	*	*	*	
MOON																		*				*	*															*				
PHASE																		> ¼																								
PLANET																						*																				
LANDMARK															*											*	*	*														
S/C-T/V DOCKED/UNDOCKED	U	D	U	U	U	U	U	U	U	U	U	U	U	U	U	D						U	U													*	D		U			U
RANGE		0														0																				*	0					*
RANGE RATE		0														0																				*	0					*
16 mm CAMERA																√						√										√				√						
PILOT LOCATION																EVA		EVA			EVA		EVA			EVA	EVA				EVA	EVA		EVA	EVA							EVA
EVA TYPE																U		S			S										U	U			S							U
UMB. EVA LOCATIONS																T/V															S/C	T/V										T/V
HELMET																																								OFF	ON	
VISOR																																									DOWN	
GLOVES																																								OFF	ON	
AC INVERTERS	IGS	IGS	ACME		IGS	IGS	IGS	IGS	IGS		IGS	IGS	IGS	ACME	*			ACME	IGS		ACME	ACME	ACME			ACME	ACME	ACME					IGS		ACME	IGS	IGS	ACME	ACME	IGS	IGS	
L. & R. CABIN LIGHTS			RED/OFF												RED/OFF			RED/OFF					OFF			OFF							OFF		RED/OFF			*	RED/OFF	OFF	OFF	
CENTER CABIN LIGHT			DIM												DIM			DIM/OFF					OFF			OFF							OFF		DIM/OFF			*	DIM/OFF	OFF	OFF	
CABIN PRESSURIZATION																0		0			0		0			0	0				0	0		0	0							0
ATTITUDE CNTL. MODE	RATE CMD	RATE CMD	PUL		PLAT	PUL	PUL	PUL	PLAT		PUL	PUL	PUL	PUL	PUL			PUL	PUL		PUL	PUL	PUL			PUL	PUL	PUL					*		*	*	*	*	PUL	PUL	PUL	
ACME BIAS POWER	PRI	PRI	PRI		PRI	PRI	PRI	PRI	PRI		PRI	PRI	PRI	PRI	PRI			PRI	PRI		PRI	PRI	PRI			PRI	PRI	PRI					*		PRI	PRI	PRI	PRI	PRI	PRI	PRI	
OAMS CONTROL POWER	ON	ON	ON		ON	ON	ON	ON	ON		ON	ON	ON	ON	ON	OFF		ON	ON		ON	ON	ON			ON	ON	ON					*		*	ON	*	*	ON	ON	ON	
PROPELLANT INDICATOR	*	*																																								
MANEUVER CONTROLLER	ON	ON									ON																									ON						
RATE GYROS (3)	PRI	PRI																					PRI					PRI					PRI		PRI			PRI				
RETICLE			√									√	√	√	√			√				√	√										√		√	√		√	√	√	√	
FDI ATTITUDE INDICATOR					WITH FDI	WITH FDI	WITH FDI	WITH FDI	WITH FDI	WITH FDI	WITH FDI	WITH FDI											WITH FDI					WITH FDI					WITH FDI		WITH FDI			WITH FDI				
SCALE RANGE					HI	HI	HI	HI	HI	HI	HI												LO																			
REFERENCE												COMP																														
MODE					ATT	ATT	ATT	ATT	ATT	ATT	ATT	ATT											RATE					RATE					RATE		RATE			RATE				
PLATFORM MODE	ORB RATE	ORB RATE			ORB RATE	ORB RATE	ORB RATE	ORB RATE	ORB RATE		ORB RATE	ORB RATE	ORB RATE		ORB RATE				ORB RATE														ORB RATE			ORB RATE				ORB RATE	ORB RATE	
ALIGNED	√	√			√	√	√	√	√		√	√	√		√				√														√			√				√	√	
COMPUTER MODE	NAV	NAV			PRE LN	PRE LN	PRE LN	PRE LN	PRE LN		NAV	NAV																					NAV									
MODULE	III	III									III	III																					III									
POWER	ON	ON			ON	ON	ON	ON	ON		ON	ON																					ON									
MDU POWER	ON	ON									ON	ON																														
START SIG		*									*	*																														
RADAR POWER																																				*	*					
BUS ARM POWER				*																																						
VOICE RECORDER			√			√	√	√	√		√				√							√	CONT			√	√	CONT				√	CONT		√	√	√	CONT	√	CONT	CONT	
AGENA ACS		OFF														ON										OFF	OFF						*		*	ON	*	*				
AGENA RECORDER																																				√	√					

NOTES:

(1) EACH ENTRY INDICATES A REQUIREMENT FOR SOME MODE OF THE EXPERIMENT FROM FLIGHT PLANS FOR GEMINI 8-12, ALTHOUGH NOT ALL ENTRIES ARE REQUIRED FOR ALL MISSIONS.
(2) ONLY NON-NOMINAL CONDITIONS ARE ENTERED FOR SOME VARIABLES, PARTICULARLY PILOT LOCATION, HELMET, VISOR, GLOVES, AND CABIN PRESSURIZATION.
(3) D-10 MODES ARE AS DEFINED FOR GEMINI 10.
(4) VARIATIONS IN STATES TO ACHIEVE A REQUIRED CONFIGURATION OR RETURN TO A NOMINAL CONFIGURATION ARE NOT INCLUDED, AS IN ATTITUDE REQUIREMENTS FOR S-13.
(5) SOME REQUIREMENTS, OMITTED HERE, ARE SPECIFIED BY OTHER CONCURRENT PROCEDURES, AS IN THE CASE OF ATTITUDE CONTROL MODES FOR S-9, ATTITUDE STABILIZATION DURING EVA FOR S-10, S-12, OR T-17, OR AN AGENA TAPE PLAYBACK TO A GROUND STATION AFTER S-26 TRIALS.
(6) REQUIREMENTS DIFFER FOR ALTERNATE CONFIGURATIONS ALLOWED FOR SOME EXPERIMENTS, SUCH AS S-11, WHICH REQUIRES PLATFORM AND COMPUTER ONLY FOR THE DOCKED MODE.

KEY OF SPECIAL SYMBOLS

* REQUIREMENT SPECIFIED BY A TABLE OR PRCEEDURAL ENTRY IN THE FLIGHT PLAN.
√ INDICATES "ON", "MOUNTED," OR OTHER DESIGNATION TRANSLATABLE AS "IN USE."

FIGURE B-1: TYPICAL NOMINAL REQUIREMENTS FOR GEMINI EXPERIMENTS.